



# UTILIZATION OF CANNY AND VELOCITY BUNCHING ALGORITHMS FOR MODELLING SHORELINE CHANGE

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## ABSTRACT

This paper introduces a new method for simulating shoreline change from multi-SAR data. Edge detection algorithm such as Canny algorithm is implemented to identify shoreline. Automatic detection of sequence of shoreline derived from historical multi-SAR data (ERS-1 and RADARSAT-1 SAR data) used to estimate rate of shoreline change. In addition, velocity bunching model used to model the spectral energy of ocean waves from multi-SAR data. Then, rate of shoreline is simulated by using velocity bunching model. The study shows that: the maximum rate of erosion is -3.0 m/year along the coastal water of Kuala Terengganu, Malaysia. There is significant relationship between shoreline change rate estimated using Canny algorithm and ones modeled using velocity bunching model. The significant relationship is shown by high value of  $R^2$  of 0.77.

## 1. INTRODUCTION

Recently there are tremendous studies have been conducted in automatic detection of coastline from various remotely sensing data (Maged 2002; and Liu and Jezek., 2004). Indeed, advance image processing tool of edge detection methods have been implemented

to identify coastline. Maged (2002) and Liu et al., (2004) utilized edge detection algorithm such as Canny for coastline detection. Further studies have been simulated the shoreline change based on volume change of sediment transport by using ERS-1 images. Maged (2003) reported that shoreline change can be easily modeled from wave spectra information have extracted from SAR images. Analytical methods introduced by Vachon et al., (1993,1994 and 1995) of modeling significant wave height from SAR data based on quasi-linear and velocity bunching models have been implemented by Maged (2001, 2002 and 2003) to predict shoreline change from ERS-1 images. The aim of this work is to utilize Canny edge detection algorithm with velocity bunching model to simulate the rate change of shoreline from historical multi-SAR data (ERS-1 and RADARSAT-1 SAR data).

## **2. METHODS**

### **2.1 Study Area**

The study area is located in the coast of Kuala Terengganu, on eastern part of Peninsular Malaysia. This area is approximately 20 km along the north of Kuala Terengganu coastline, located between  $5^{\circ} 21' N$  ,  $103^{\circ} 10' E$  and  $5^{\circ} 30' N$ ,  $103^{\circ} 20' E$ . Sand materials make up the entire of this beach (Maged 2000). The east coast of Peninsular Malaysia is annually subjected to the northeast monsoon wind (November to January) (Stanley, 1985) under study showed that the mean and longer significant wave periods were 8 to 10 seconds. Significant wave heights maximum have reported by were 4 m and 2.4 m, respectively which are experienced in February and March. However, during the southwest monsoon wave height was ranged between 0.4m -0.7m (Maged et al., 2002). During the inter-monsoon period (September to mid of November), the wave height was ranged between 0.37m to 1.6 m (Maged 2002).

### **2.2 Data Acquired**

SAR data used in this study are involved ERS-1 and RADARSAT-1 SAR data. ERS-1 data in the  $C_{vv}$  band (12.5 m) is acquired on 12 December 1999. The in situ wave measurements data were obtained from Malaysian PETRONAS oil platform observation through Malaysian Meteorological Service. RADARSAT-1 SAR image is acquired on March 30 2005 with standard 2 mode. During its pass over in situ measurements collected by using AWAC wave rider buoy.

### 2.3 SAR Velocity Bunching Model

The velocity bunching MTF is the dominant component of the linear MTF for the ocean waves with an azimuth wave number ( $k_x$ ). According to Vachon et al., (1994 and 1995), the velocity bunching can contribute to linear MTF based on the following formula

$$M_v = \frac{R}{V} \omega \left[ \frac{k_x}{k} \sin \theta + i \cos \theta \right] \quad (1)$$

where  $R/V$  is the scene range to platform velocity ratio,  $\theta$  is ERS-1 and RADARSAT-1 SAR incidence angles ( $23^\circ$  and  $27.49^\circ$ ) and  $\omega$  is wave spectra frequency which equal  $2\pi/K$ . To estimate the velocity bunching spectra  $S_{vb}(k)$ , we modified the algorithm that was introduced by Krogstad and Schyberg, (1991). The modification is to multiply the velocity bunching MTF by ERS-1 SAR and RADARSAT-1 SAR spectra variance of the azimuth shifts. This can be given by

$$S_{vb}(k) = [I_0 \sum_{n=1}^{\infty} \frac{\psi(k_x)^{2n}}{n!} S_{\zeta\zeta}^{*n} \psi(k)^2 e^{-K_x^2 \rho_{\zeta\zeta}}] [M_v] \quad (2)$$

where  $S_{\zeta\zeta}$  is the SAR spectra variance of the azimuth shifts due to the surface motion, which induced by the velocity bunching effect in azimuth direction due to high value of  $R/V$ .

The relation between standard deviation of the azimuth shift and significant wave height can be given by

$$\sigma = \left(\frac{R}{V}\right) \left(1 - \frac{\sin^2(\theta)}{2}\right)^{0.5} \left(\frac{k_x g}{8}\right)^{0.5} H_s \quad (\text{Vachon et al., 1993}) \quad (3)$$

where  $k_x$  is the azimuth wave number. Note that the mean wave period  $T_0$  is equal to  $2\pi(\langle\langle k_x \rangle\rangle g)^{-0.5}$ . Using equation 3 with equation 4, so the significant wave height can be given as

$$H_s = 0.6(\rho_{\zeta\zeta})^{0.5} \left[ \frac{1 + \theta^2/4}{R/V} \right] T_0 \quad (4)$$

where  $\theta$  is the ERS-1 and RADARSAT-1 SAR incidence angles and equation 4 is used to estimate the significant wave height which is based on the standard deviation of the azimuth shift. The significant wave height determined using velocity-bunching model then

used to model the rate of volumetric sediment transport based on the depth of significant wave breaking by using the following formula derived from Maged (2003)

$$H_{sb} = 0.4g^{1/5} \left[ \left[ (0.6\sqrt{\rho_{\zeta\zeta}} \left( \frac{1+\theta^2/4}{R/V} \right) T_0)(T) \right]^2 \right]^{2/5} \quad (5)$$

According to Maged 2003, the along-shore sediment transport volume rate  $Q$ , is calculated as

$$Q = 1.1\rho g^{3/2} (H_{sb})^{5/2} \sin \alpha_b \cos \alpha_b \quad (6)$$

where  $\rho = 1020 \text{ kg/m}^3$  for sea water and  $\alpha_b$  is the breaking wave angle estimated from linear wave transformation model. The ambiguity of SAR wave spectra are resolved by using the sea direction in situ measurements. According to Maged (2002) the shoreline change rate based on volume change of sediment transport can be estimated by following equation

$$\int_{x_0}^x y dx = - \int_{t_0}^t 2hQ dt \quad (7)$$

where  $t$  is period of change and  $x$  is along shore distance and  $h$  the depth of closure (m).

## 2.4 Automatic Detection of Shoreline

According to Maged (2002) the shoreline of east Coast of the Peninsula of Malaysia is defined by the boundary between vegetation and the bar sandy area (beach). Following Maged (2002) Canny algorithm has applied to SAR images after performing linear filters by using Guassian and Lee algorithms. The Canny algorithm has applied as follows: The input of the SAR image intensity  $I$ , which is corrupted by noise. Let  $G$  be a Gussian with zero mean and standard deviation  $\sigma$ . The value of  $\sigma$  to be relied on the length of interesting connected contours, the noise level, and the localization-detection trade off. The Gaussian algorithm was applied and smoothens the image intensity to image  $J$  i.e.,  $J = I * G$  for each pixel  $(i,j)$ : (a) compute the gradient components,  $J(x,y)$  (b) estimate the edge strength as given by

$$e_x(i, j) = \sqrt{J_x^2(i, j) + I_y^2(i, j)} \quad (9)$$

The historical edge detection vectors then overlaid and the rate change ( $R$ ) of shoreline estimated by given simple formula ( Maged 2001)

$$R = \frac{x_n - x_0}{t_n - t_0} \quad (10)$$

where  $x$  is the horizontal measured distance between initial vector ( $x_0$ ) of ERS-1 image and second vector  $x_n$  of RADARSAT-1 SAR image over period  $t$ .

## 2.5 Field Work

Beach profile survey has been conducted during the RADARSAT-1 SAR pass over coastal water of Malaysia. Profile survey is carried out by using level and staff methods. Theodolite is fixed on front between vegetation and sand. Then poles are fixed at every slope point. Furthermore, Global Position System (GPS) has used to collect geographical coordinates of selected 10 locations (Figure 1), where the interval distance between every location was 2 km. Additionally, the ground data information has used to acquire more precisely geomatic correction processing for multi-SAR data. Finally, accuracy validation is performed by comparing between multi-SAR and ground data.

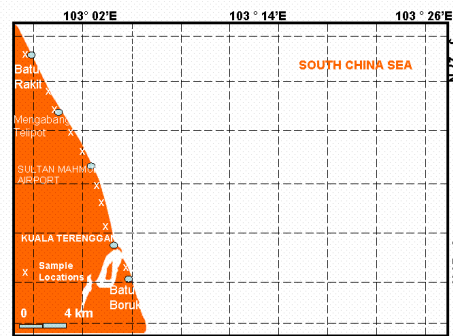
## 3. RESULTS AND DISCUSSION

Figure 2 shows the significant wave height modeled by using velocity bunching model from ERS-1 and RADARSAT-1 SAR images. In December 1999 (ERS-1 SAR), significant wave heights are ranged between 1.2 to 3.2 m while in March 2005 (RADARSAT-1 SAR), significant wave heights are ranged between 0.2 to 0.7 m. Regression model shows that the significant wave heights modeled by velocity bunching are in good agreement with in situ data. The degree of correlation is a function of  $r^2$  and probability ( $p$ ). The relationship between velocity bunching model and in situ data shows positive correlation as  $r^2$  values for both ERS-1 and RADARSAT-1 SAR data are 0.69 and 0.73, respectively. According to Maged (2004) velocity bunching model produces precisely information of wave spectra. Indeed, it is able to solve the matter of non-linearity between SAR observed spectra and ocean wave spectra. On other words, it can be used to map SAR observed spectra into real ocean spectra. This result confirms that studies of Vachon et al., (1993) and Maged

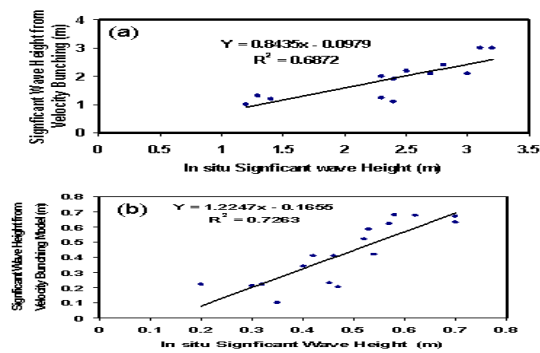
(2004). Figure 3 shows the result of Canny algorithm. It is interesting to notice that Canny algorithm is provided an automatic digitizing for shoreline. Furthermore, it is also clear that small texture details have detected. Indeed, Canny algorithm can perform pseudo-edge appearance. Additionally, the concave coastline is detected which is obvious along the coastline of Sultan Mohamed Airport. Maged (2002) stated that Canny algorithm produces pixel wide skeleton curves and able to extract the sequences of pixels along this curve. He concluded that each curve contains sequences of pixels is able to convert to vector layer by fitting piecewise line segments to it. In addition, Canny is able to produce a polyline is an approximation to the original pixel curve. Which could link pairs of polylines. Figure 4 shows the comparison between shoreline change rate simulated by velocity bunching and one based on historical vector layers extracted by Canny algorithm and ground data measurements. The different sorts of data are agreed that the high rate of erosion is recurred along the Mengabang Telipot coastline with maximum values of -3.0, -2.8, -2.6m/yr obtained by velocity bunching model, Canny algorithm and ground beach profile surveying. Meanwhile, Sultan Mohamed airport is encountered high rate of erosion within maximum values of -2.4, -2.00, -1.93 m/yr modeled from velocity bunching model, Canny algorithm and ground beach profile data collection. The sedimentation events have been observed along mouth river of Kuala Terengganu and Batu Bourq within average values of 1.89 m/yr which are acquired from velocity bunching ,Canny algorithm and ground data. Table 1 shows significant relationship between Velocity Bunching model and Canny algorithm with  $R^2$  of 0.70.

#### **4.0 CONCLUSION**

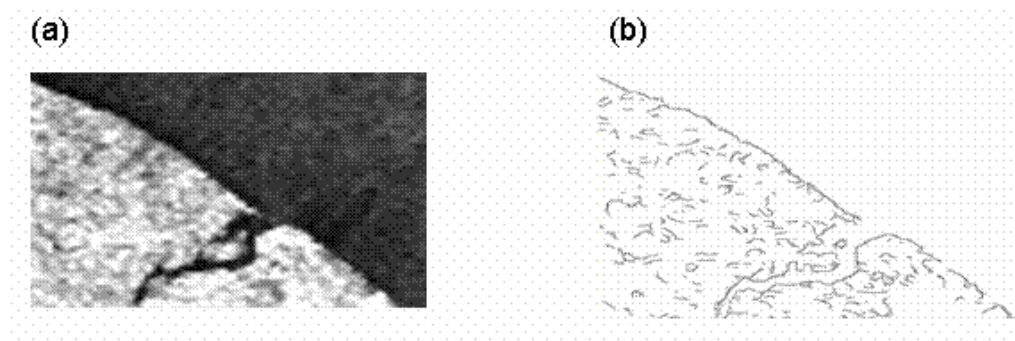
This study has been demonstrated a new technique for modeling shoreline change based on velocity bunching model and Canny algorithm. It can be said that modification of sediment transport model based on velocity bunching model can be used to simulate rate change of shoreline from multi-SAR data. In fact, velocity bunching is provided a quantity information on significant wave height from SAR data such as ERS-1 and RDARSAT-1 SAR images. It can be concluded that integration between velocity bunching model and Canny algorithm is considered as usefual tool for modeling quantity of shoreline change pattern.



**Figure 1** Location of Study Area

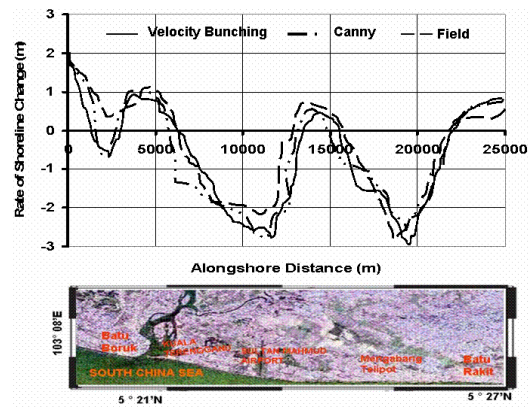


**Figure 2** Significant wave Height Modeled by Velocity Bunching Model (a) ERS-1 and (b) RADARSAT-1 SAR images



**Figure 3** Example of Canny Algorithm (a) Raw SAR data (b) Output Result of Canny





**Figure 4** Rate Change of Shoreline from Canny, Velocity Bunching and Field data.

**Table 1** Statistical Analysis between Velocity Bunching, Canny and Field Data

Methods	R2
Velocity Bunching-Canny	0.70
Velocity Bunching-Field	0.68

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